

him for the first time, and has remained a permanent and indispensable feature of steam prime movers of all types when working condensing.

Further improvements, with the object of conserving the heat in the steam, were made by Watt, who was the first to comprehend that the steam cylinder should be kept as hot as the steam which enters it. The top of the cylinder was closed by a cover through which the piston-rod passed, a stuffing box being used. A steam jacket was added, and the whole cylinder was lagged with non-conducting material, in order to prevent loss of heat by radiation. Steam was allowed access to the whole space above the piston, with the object of keeping the cylinder warm, its pressure performing the same function as the atmosphere in Newcomen's engine. Watt's first engine, therefore, worked on a similar cycle, the sole difference being that the working steam from the under side of the piston escaped from the cylinder at the termination of the upstroke and was condensed in a separate vessel.

Later, expansive working of the steam was introduced, again raising the efficiency, and the engine was made double-acting, that is, each side of the piston was put into communication alternately with the boiler and the condenser. These changes practically completed the series of wonderful improvements introduced by the genius of Watt in the use of steam as a working fluid in a heat engine, and it is interesting to note that they were effected in complete ignorance of the equivalence of heat and work, which long afterwards was established by Joule.

Other inventions, not less valuable, followed, such as the parallel motion, the centrifugal governor, the indicator, &c., all of which aided the development of the steam-engine as a working machine. The slide valve was introduced by Murdoch, one of Watt's assistants. The application of the crank and connecting-rod brought the engine into general use for all purposes for which rotative motion is necessary, and led to a world-wide development in industries of all kinds.

A new cycle was introduced in the large engines used in Cornwall for the pumping of water from the mines, and therefore

was called the
" Cornish " cycle. The working stroke was downwards,
steam being
admitted from the boiler above the piston and cut off
comparatively early.
At the bottom of the stroke the steam above the piston was
allowed to pass
to the under side by a so-called equilibrium valve being
opened, so that
by the time the upstroke was completed the whole of the
steam had been
transferred from the top side to the under side of the
piston. At the
commencement of the next downstroke a valve was opened,
which allowed
the whole of the steam below the piston to flow into the
condenser, thus
causing a vacuum to be formed below the piston. By this
artifice the
upper portion of the cylinder was never in communication
with the con-
denser, and the process of " initial condensation " was
thereby reduced,
giving much improvement in economy, so that the Cornish
pumping-
engine attained an efficiency rivalled only by high-pressure
multiple-
expansion engines of to-day, if the systematic records of
the performance